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A Model of Small Capacity Power Plant in Tateli Village, North Sulawesi

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Abstract. The electricity supply in North Sulawesi is still very limited so ubiquitous electric current outage. It makes rural communities have problems in life because most uses electrical energy. One of the solutions is a model of power plants to supply electricity in Tateli village, Minahasa, North Sulawesi, Indonesia. The objective of this research is to get the model that generate electrical energy for household needs through power plant that using a model of Pico-hydro with cross flow turbine in Tateli village. The method used the study of literature, survey the construction site of the power plant and the characteristics of the location being a place of research, analysis of hydropower ability and analyzing costs of power plant. The result showed that the design model of cross flow turbines used in pico-hydro hydropower installations is connected to a generator to produce electrical energy maximum of 3.29 kW for household needs. This analyze will be propose to local government of Minahasa, North Sulawesi, Indonesia to be followed.

1. Introduction

North Sulawesi region more specifically in the villages of Minahasa district has a mountainous topography and has many rivers which is a potential source of enormous energy for power plants which, when carefully planned can overcome the problem of electric energy crisis. Problems that have long and at this time every day power outage for about 2-3 hours a day. However, the electricity crisis was not so much solved using the integral energy source potential flow of river water in the area of North Sulawesi. There are still many villages far from urban areas still do not have adequate power supply [1]. In anticipation of that, it is necessary to build small-scale power plants (1 kW - 5 kW).

Figure 1 shows that the electrical energy production by 2013 in the province of North Sulawesi using water power is still very little 9.02% [2]. It shows that the construction of the hydroelectric power plant is still very much needed in the area of North Sulawesi. Shortage of electricity in rural areas is very likely to occur because it is far from the urban and the power grid, but did not rule urban areas are also experiencing the same thing. In fact, many cities and districts that rely on diesel and hard to come by when the oil, resulting in a power outage in rotation may even are expanded. One solution is emerging development in Indonesia at this time is to find a way out through the construction of power plants micro scale with the power source stream flow and more dependable again when rural communities require the construction of power plants as small as possible, namely less than 5 kW and that can be realized through pico-hydro power plant (PLTPH).

During this time there is a kind of consensus that development PLTPH must have a double impact, not only to improve the provision and equitable distribution of power supply, especially in rural areas but also makes the vehicle to improve the ability of local industry to address the development PLTPH starting from feasibility studies, planning, manufacturing machinery and equipment, to the realization of the installation. In addition PLTPH development pattern aligned with the level of presence in the form of appropriate technology in rural areas. Rural technology in irrigation development people get almost the same pattern with the construction PLTPH, just need refinement for power knows no season. PLTPH itself is an intermediate technology that has been applied since long ago and is expected to have a positive impact or benefit for the creativity and dynamism of society in lifestyle in order to improve the welfare of rural communities. It is becoming urgency in this study in addition to the efficiency and effectiveness of the construction of power plants, especially in the energy forces turn turbines and planning / selection of appropriate turbine to turn a generator needs to be analyzed.

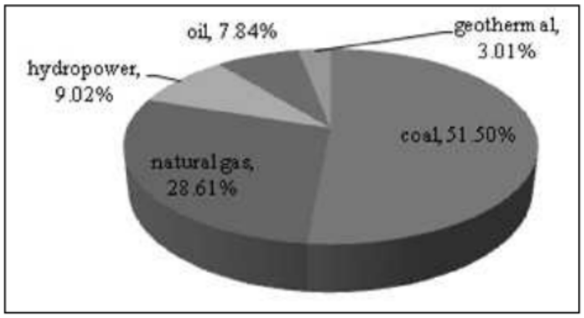

Figure 1. Production of electric energy in North Sulawesi (2013)

Based on the analysis of the energy force of the waterfalls and design analysis turbines, all of which were made through experiments in the laboratory and in the field (in the village where the installation location) to the mounting PLTPH and generate electrical energy production is less than 5 kW is an invention/innovation targeted in research this. PLTPH development is to be realized in the villages Minahasa North Sulawesi province are in accordance with the roadmap of the Indonesian government as shown in figure 2 [3]. In the period 2015-2025, the government has planned the role of government research and development (R & D) that update data on potential PLTPH in the area and manufacturing feasibility study PLTPH, development turbines PLTPH the efficient use of technology crosflow, propeller, and kaplan and system development capacity of 750 kW and the role of manufacturing industries seek turbine development results. Based on the role of government and industry in the 2015-2025 year, the study is in conformity with the government's plan 2015-2025 year on R & D activities are potential PLTPH map updates and the total development of the system. Was further strengthened by the government of North Sulawesi province that integrate and provide services to the activity centers in the region of North Sulawesi province with the publication of the North Sulawesi provincial regulations No. 1 Year 2014 on Spatial Planning of North Sulawesi province from 2014 to 2034 Year Article 22 (a) and 23 (a) that the government regulates the energy network system includes one electric generating system in Minahasa [4].

For the creation of the PLTPH development, it previously had to be done: first, about the theoretical studies as the basis for analysis through literature; second, conduct survey research sites (including survey the village is selected villages that have the potential to obtain characteristics of the villages and communities for the purpose of character education for these communities through socialization to shape the character of the community so that there is a sense of belonging and accept, help build and maintain the power plant in village) in the form of: discharge of river water, river water dam layout, long conductive flow of water to the location of the water falls, the water level fell, and location of turbines; Third, experiments in laboratory experiments in the form of high variation of water falling; Last, economic analysis and supply to the local government Minahasa district for expansion into other villages potentially built PLTPH.

Pico-hydro is hydro power with a maximum electrical output of 5 kW [5] [6] [7]. The system is beneficial in terms of cost and simplicity from a different approach in the design, planning and installation from the power applied to the water is greater. The latest innovations in pico-hydro technology have made an economic powerhouse even in some of the poorest places in the world and can be accessed. It is also a versatile resource. AC electricity possible can be produced from a standard electrical equipment to be used. Common examples of devices that can be powered by pico-hydro are light bulbs, radio and television.

Typically, pico-hydro power systems are found in rural areas or hilly. Figure 3 shows an example of a typical application of pico-hydro hydro system in hilly areas [7][8]. This system will operate using a container of water on which a few meters from the ground. From the reservoir, the water flows downhill through the piping system and it allows the water to turn turbines. Thus, the turbine will rotate the alternator to produce electricity. However, this study was conducted to demonstrate the potential of consuming water that is distributed to homes in rural areas as an alternative renewable energy source. The flow of water in the pipe has the potential and kinetic energy will be converted into the potential energy of motion of the turbine which then into electrical energy in generators.

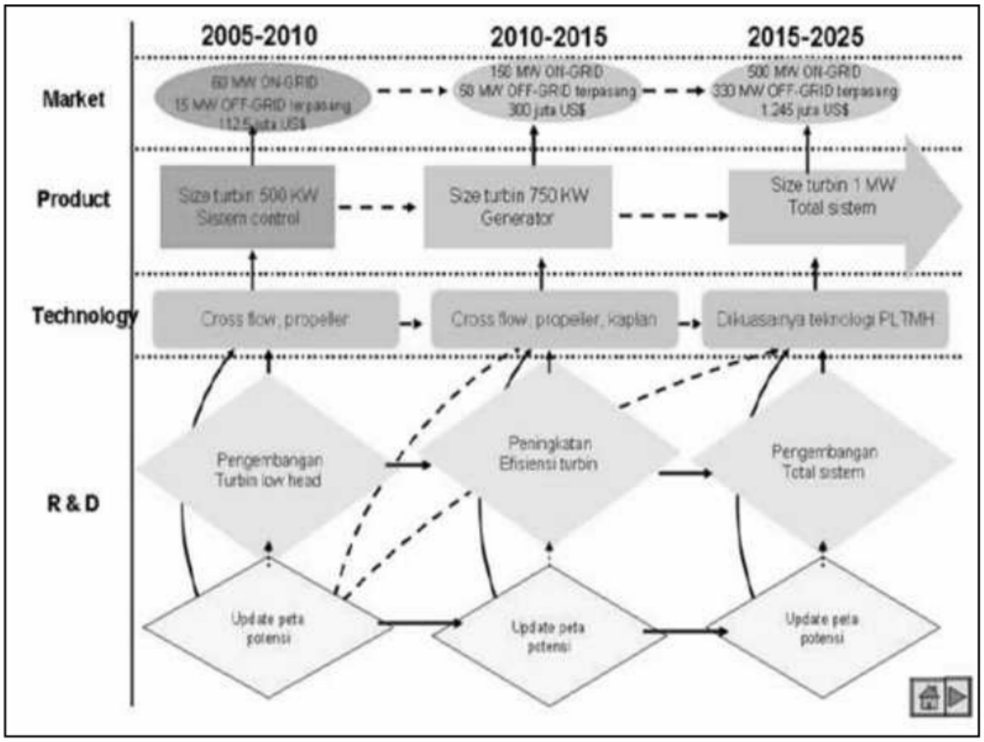

Figure 2. Roadmap of PLTPH development in Indonesia

Technically, pico-hydro has three main components: water (as a source of energy), turbine and generator [9] [10]. Pico-hydro get energy from the flow of water that has a certain altitude difference. Basically, pico-hydro utilized the potential energy of water falling (head). The higher the water falls, the greater the potential energy of water that can be converted into electrical energy. In addition to geographical factors (layout of the river), the height of falling water can also be obtained by stemming the flow of water so that the water level is high. Air flowed through a pipe plant rapidly into the house in general was built on the banks of the river to drive turbines or waterwheels pico-hydro. Mechanical energy derived from rotation of the turbine shaft is converted into electrical energy by a generator.

The objectives of this research is to get the model of efficient and effective from cross flow turbine models for installation in PLTPH which generates electrical energy production of less than 5 kW for a household in the village Tateli Minahasa North Sulawesi.

1.1. Impulse Turbine
The principle works: water flowing perpendicular to the turbine shaft through the rapidly incoming pipe high speed and push the rotor blades of the turbine, causing the turbine rotor rotation [9] [10] [11]. The pressure drop in the water flow in the nozzle and the turbine wheel operates at atmospheric pressure. The examples of Cross flow Impulse Turbines (figure 4) are a Pelton wheel, wheel Turgo and crossflow turbine (Banki-Michell). Impulse turbines generally operate best with medium or high head above 10 m.

1.2. Reaction Turbine
Reaction turbines operate under pressure inside the stator (casing). When water passing through the stator in the direction of the turbine shaft helical, causing a whirlpool. The flow was then directed by the blades of the turbine wheel. The angular momentum of the forces in the water rotates the turbine wheel. In contrast to the impulse turbine, the water pressure drops in the stator and the turbine wheel. Examples of a reaction turbine (figure 5) is Propeller (propeller), Kaplan, and Francis, Screw and kinetic turbines water (used to lower head is less than 5 m). Reaction turbines often have houses and geometry turbine blades of a complex which makes it more difficult to process large scale production of the smallest in the settings in developing countries. However, the reaction turbine can perform well even in low head distance of less than 10 m, thus making it more desirable since the low head of water resources are more accessible and closer location. Water turbines can be classified in two categories namely [11] [12]:

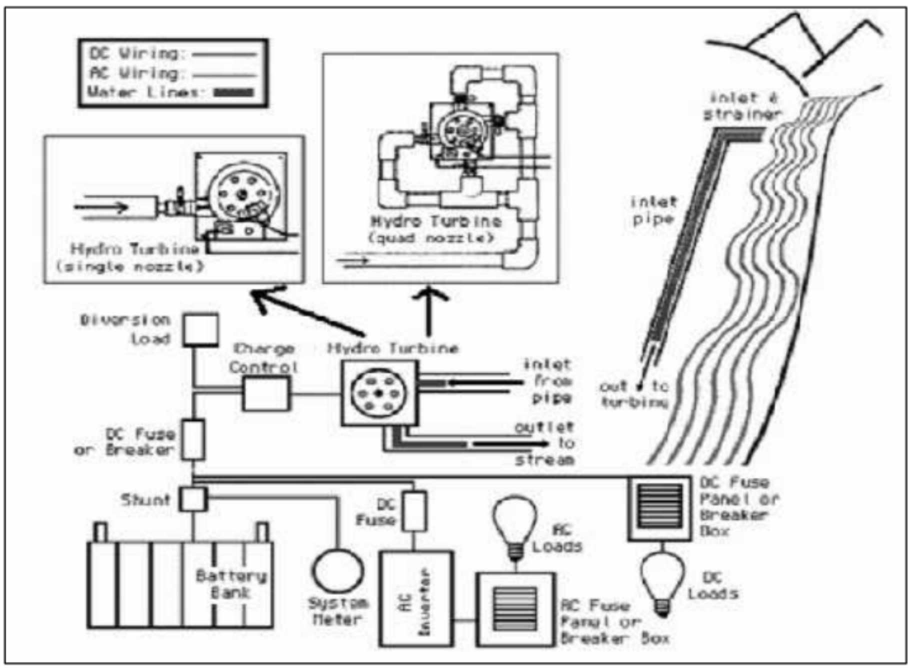

Figure 3. Examples of application of pico-hydro power systems in rural areas

Turbin power (P_t) defined [9] [10]:

$$P_t = \rho. \quad (1)$$

where ϱ is water density (1000 kg/m^3), g is gravity (m^2/s), H is head, Q is water flow (m^3/s), and □is turbine efficiency (normally 70-80 % depend on turbine type).
Calculation of Electric Power and Energy:
Power turbine shaft:

$$P_t = 9.81Q \tag{2}$$

Power is transmitted to the generator:

$$P_{t_i} = 9.81Q \quad \eta_b \tag{3}$$

Power generated generator:

$$P = 9.81Q \quad \eta_b \quad \eta_g \tag{4}$$

Where □= turbine efficiency (0.74 and 0.75 for the cross flow turbine to turbine axial), □$_{belt}$ = transmission efficiency, 0.98 for a flat belt, 0.95 for the V belt, □$_{gen}$ = generator efficiency

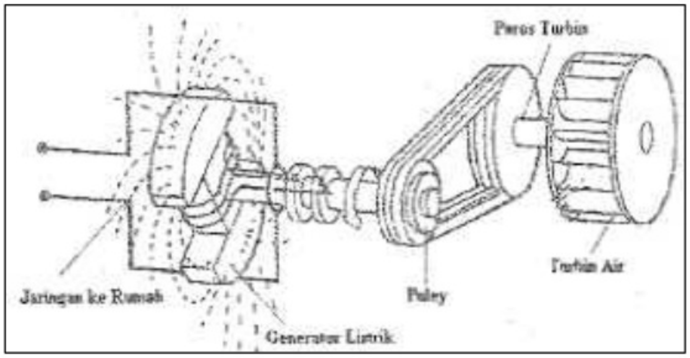

Figure 4. Type of crossflow impulse turbine

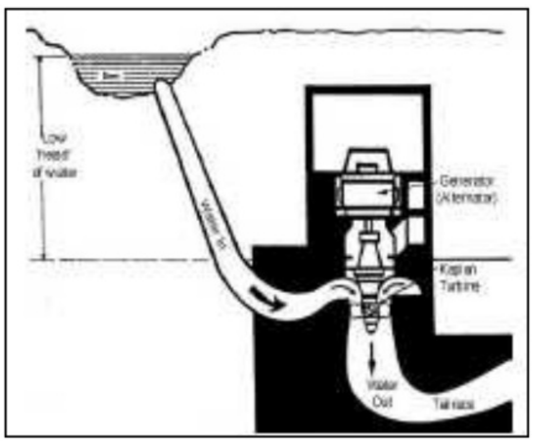

Figure 5. Type of axial reaction turbine

This generator power generated will be distributed to users. In planning the required amount of power at the load center should be under the power capacity is raised, so that the power supply voltage is stable and the system becomes more reliable (long).

The water flowing with capacity and a certain height distributed to the house installation (casing). At home the turbine, the water plant will pound turbine, turbine ascertained in this case will receive the water energy and convert it into mechanical energy in the form of turbine shaft rotation. The rotating shaft is then connected to the generator by using the tire/belt. Of the generator will produce electricity that will go into the control system before the electrical current supplied to homes or other purposes (load). That briefly the process of pico-hydro, alter energy flow and water level into electrical energy [10].

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2. Approach method

The method used literature study, site survey research (including survey the village in order to obtain the characteristics of villages and rural communities Tateli for the purpose of character education for these communities in receiving, helped build and maintain the power plant), analysis beginning on the ability of electric power, and discussions with local authorities (see figure 6). Conducting preparatory activities before carrying out such research; reflecting the result of socialization, preparation of materials and experimental tools, setting work schedules. Data collection in the village Tateli form: discharge of river water, water velocity, channel length conductor, high waterfalls, and location of the turbines. Methods of direct observation in the field through measures such as speed streams and cross-sectional area perpendicular to the water flow of the river to get water discharge flowing river as initial data in the analysis of the ability of river water, and then to analyze the electrical energy taken preliminary data height measurements falling water (planned 1.34 m) including measuring the distance from the dam to the water fall. Technique of direct measurement with the following procedure: first measure the water velocity and the second measuring cross-sectional area perpendicular to the flow of river water in order to get water discharge (cross-sectional area multiplied by the speed of the water, m^3/s), and the last measure the height of falling water to get the length of the aqueduct of dam water to the waterfall.

Figure 6. Location of research in village Tateli, Minahasa

Analyze and calculate a preliminary survey in the form of the findings of the theory through literature, site survey and collection of field data and then analyze the debit mainstay and planning ability hydroelectric developed in the planning and continued in the field with a pass calculation electrical energy through analysis of turbine and generator, voltage, and power generated. Finally, proceed with analyzing the PLTPH development costs.

3. Results and discussion

The analysis results of water capability that obtained from basis of the gross calculation before analysis further can be seen in table 1. The water discharge (Q) is planned to enter the pipe rapidly with water fall head of 1.34 m and if we calculate minimum water flow of 20% of the water flow was then obtained

91.61 litre/s. Generates power without taking into account the total efficiency of 5.12 kW and if we take into account the total efficiency of 0.643, the installed power of 3.29 kW.

Table 1. Results of water and power capability analysis

Q (m^3/s)	H_{bruto} (m)	H_{losses} (m)	H_{eff} (m)	P (kW)	P' (kW)
0.458	1.34	0.134	1.2	5.12	3.29

Table 2 shows the results of the analysis of electrical energy which is calculated based on the total efficiency, the force of gravity, high falls and the actual effective water obtained from the difference between the height of fall slop and total loss of height of falling water (0.1 m previously planned 0.134 m). The total energy obtained during a year high real effective water fall of 1.2 m was 29.335 MWh with installed power of 3.29 kW. Total electrical energy obtained within a year of 29,335 kWh. If we calculate the value of selling electricity to PLN by calculating the total cost of expenditure per year of IDR 25 million, the value of the electricity sold at IDR 852/kWh.

All of the results are showed that the electrical energy needs can be fulfiled not only for the village Tateli but also other villages nearby. So as to realize it, then the results of this study will be proposed to local governments Minahasa to be realized in order to meet the needs of not only domestic but also for street lighting and other facilities available in the village Tateli.

Table 2. Results of electrical energy analysis

$\Sigma\eta$	H_{eff} (m)	Q_{80} (m^3/s)	Q_{90} (m^3/s)	Q_{100} (m^3/s)	ΣE (MWh)
0.643	1.2	0.458	0.407	0.254	29.335

4. Conclusions

The ability of hydroelectric power of 5.12 kW is installed or the electrical power produced by the capability of the water. The effective head of 1.2 m with the generated power of 3.29 kW and water flow of 0.458 m^3/s. The total energy is obtained within a year is 29.335 MWh. The electrical needs could be satisfied in Tateli. This model will be proposed to local government of Minahasa, North Sulawesi, Indonesia to be followed.

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